RESTRICTED CIRCULATION

This paper is not an official document; it is for information only and reference cannot be made to it in any printed publication without the permission of the author.

AGRICULTURAL MEMORANDUM NO.533

Estimating the Frost Risk for Horticulture

J W DAVIES

INTRODUCTION

Methods of estimating the frost liability at different sites in an orchard or on a horticultural holding, have concerned the Agricultural Branch of the Meteorological Office, since its inception in 1948.

This memorandum sets out a revised method of such estimation and is a development of that used at Bristol over recent years. The new method is described in detail, and it is tested on long term data from Long Ashton and Ross on Wye.

METHOD

A base station is required for which daily minimum temperatures are available for a long period. For this investigation Long Ashton data from 1925 to 1971 were used. The period under consideration is confined to the eight weeks from April 1-7 (week 1) through to May 20-26 (week 8), the final date being taken as the end of the frost season.

For each year, the extreme daily minimum temperature is noted for each of the eight weeks. These weekly minima are then combined to give the lowest minimum temperature that occurs on or after the start of each week, ie for weeks 1-8, 2-8, 3-8, 4-8, 5-8, 6-8, 7-8 and week 8. For each of these periods of combined weeks, the frequency of each minimum temperature is calculated, and this is finally expressed as the number of years in 10 when the minimum temperature occurs, see Table I.

From these values a series of smoothed curves are drawn, one for each period (see Figures 1 and 2). Alternate periods are plotted on the figures for clarity and convenience of use.

ASSUMPTION

It is assumed that the curves showing the frequency of extreme temperatures at a base station are representative of the site under analysis, providing a constant temperature shift is incorporated, representing the difference in minimum temperature between the base station and the trial site.

A measure of such temperature differences may be obtained in a number of ways, and three of these were considered:

a) Comparison of the extreme weekly minima

b) Comparison of the mean of the three lowest daily minima each week

c) Comparison of the mean daily minima for each week

The values thus obtained were then combined for each of the periods previously used for the base station.

Previous workers had suggested that the use of mean weekly minimum temperatures was suspect since it included nights when weather conditions were such, that the minimum temperatures were much the same from site to site, and it tended to obscure the nights when large temperature differences existed between sites.

It quickly became clear that using method (a) was unreliable, and it was discarded. It was decided therefore, to make an extensive check to compare both methods (b) and (c).

ESTIMATION METHOD AND CHECK

Daily minimum temperatures were obtained for Ross on Wye for the period 1930 to 1971. From these data long term frequencies were obtained of the average number of years in 10 when temperatures of 32°F or less occurred. Similar frequencies were obtained for temperature levels of 30°F and 28°F. These temperature levels were selected because experience has shown that, dealing with blackcurrants, it is reasonable to assume that if there is no frost protection, then there will be a considerable loss of crop with a minimum temperature of $\leqslant$ 28°F in April and May, and a partial loss (up to 50%) with temperatures $\leqslant$ 30°F. The frequencies of the temperature levels thus indicate the probable cropping over 10 years without frost protection, and hence the benefit to be gained from adequate protection. For example, if the frequencies show 8 years out of 10 at $\leqslant$ 32°F, 5 years at $\leqslant$ 30°F and 3 years at $\leqslant$ 28°F, we can assume:

little or no crop in 3 years

50% loss in a further 2 years

very slight loss in a further 3 years

and no loss in 2 years

Other temperature levels relevant to other crops could equally well be chosen.

For each year 1930-71, estimates were made of the long term frequency at Ross on Wye for the three temperature levels using both methods separately to determine the temperature adjustment. Tables II and III show the estimates made using minimum temperatures recorded in 1930. The estimates were finally smoothed and were then expressed as differences from the known long period frequency at Ross on Wye. Table IV gives the number of estimates that were within $\pm$ 0.5 and $\pm$ 1.0 years of the actual frequency, and also the standard deviation of the differences. This table clearly illustrates the greater reliability obtained, using estimates of frost frequency based upon the mean daily minima for each week.

SUMMARY

Before a decision is made to plant a frost susceptible crop, such as blackcurrants, a necessary management input is an indication of the number of years when yields are likely to be affected by damaging frosts in spring.

A method is described showing how such frequencies may be obtained, by comparing minimum temperatures recorded at the proposed site, with those at a nearby station for which long period frequencies are available. An eight week period is considered between 1 April and 26 May. Estimates of the frequencies are shown to be accurate to within one year in ten on at least 74% of occasions. If only severe frosts ($\leqslant$ 28°F) are considered then at least 93% are accurate within one year in ten. These comparisons relate to stations about 35 miles apart with dissimilar surroundings. It is considered that greater accuracy could be obtained if the two stations were nearer or if two seasons were available for the comparison.

It is probable that estimates will be required for more than one site at the holding. 'Cocoa tin' thermometer mounts are normally used at each site, in conjunction with one normal screen at the holding. The daily correction needed to convert the 'mount minima' to the screen minima is thus obtained.

Any comments or suggestions on this paper should be sent to the author.

Meteorological Office
ADAS
Burghill Road
Westbury on Trym
Bristol
BS10 6NJ

MARCH 1973

TABLE I LONG ASHTON 1925-1971

Cumulative Frequency of Extreme Minimum Temperatures between start of given week and end of week 8, expressed as years in 10

	Weeks							
	1-8	2-8	3-8	4-8	5-8	6-8	7-8	8
25°F	0.6	0.6	0.6	0.2	0.2	0.0	0.0	0.0
26°F or less	1.3	0.9	0.6	0.2	0.2	0.0	0.0	0.0
27°F	1.9	1.3	1.1	0.6	0.4	0.0	0.0	0.0
28	3.2	2.1	1.7	1.3	0.6	0.4	0.4	0.0
29	3.8	3.4	2.6	1.7	1.1	0.4	0.4	0.0
30	6.0	5.1	3.6	2.6	1.7	0.4	0.4	0.0
31	7.2	6.4	4.7	3.8	3.2	1.3	0.9	0.2
32	8.5	7.7	6.6	5.7	5.1	2.6	1.3	0.2
33	9.6	9.1	8.3	7.9	6.6	3.4	1.7	0.4
34	9.8	9.6	8.5	8.3	6.8	4.0	2.6	0.9
35	9.8	9.8	9.6	8.9	7.7	6.0	3.8	1.9
36	9.8	9.8	9.6	8.9	7.9	6.6	4.3	2.3
37	9.8	9.8	9.6	9.4	8.5	7.2	5.3	3.8
38	10.0	10.0	9.8	9.8	9.4	8.1	7.2	4.5
39			9.8	9.8	9.6	8.7	7.4	4.7
40			10.0	10.0	10.0	9.1	7.7	4.7
41						9.6	9.1	6.4
42						9.8	9.8	8.7
43						9.8	9.8	9.4
44						9.8	9.8	9.4
45						10.0	10.0	9.8
46°F or less								10.0

TABLE II ESTIMATION OF FROST FREQUENCIES AT ROSS ON WYE 1930
using 3 lowest daily minima each week. Base station: Long Ashton

		Weeks							
		1-8	2-8	3-8	4-8	5-8	6-8	7-8	8
1. Trial Site Cumulative means		39.7	39.9	40.1	40.5	40.9	42.3	44.1	45.3
2. Base Station " "		38.7	38.7	39.0	39.9	39.7	41.4	43.0	44.7
Difference (1-2)		1.0	1.2	1.1	0.6	1.2	0.9	1.1	0.6
Corrected Base Station	(= 32°F	31.0	30.8	30.9	31.4	30.8	31.1	30.9	31.4
temperature for	(= 30°F	29.0	28.8	28.9	29.4	28.8	29.1	28.9	29.4
site temperature	(= 28°F	27.0	26.8	26.9	27.4	26.8	27.1	26.9	27.4
Frequency (years in 10)	(≤ 32°F	7.2	6.1	5.1	4.5	2.7	1.4	0.8	0.2
from Base Station	(≤ 30°F	4.5	3.0	2.5	2.1	1.0	0.5	0.3	0.0
graphs	(≤ 28°F	2.0	1.2	1.0	0.8	0.3	0.1	0.0	0.0
Smoothed frequencies	≤ 32°F	7.2	6.1	5.1	3.8	2.5	1.3	0.8	0.2
	≤ 30°F	4.5	3.4	2.5	1.7	1.0	0.5	0.1	0.0
	≤ 28°F	2.0	1.5	1.1	0.8	0.3	0.1	0.0	0.0

TABLE III ESTIMATION OF FROST FREQUENCIES AT ROSS ON WYE 1930
using mean daily minima each week. Base station: Long Ashton

1. Trial Site Cumulative means		42.8	42.9	43.1	43.8	43.7	45.0	46.9	48.3
2. Base Station " "		42.1	42.1	42.3	43.3	43.1	44.5	46.5	48.6
Difference (1-2)		0.7	0.8	0.8	0.5	0.6	0.5	0.4	-0.3
Corrected Base Station	(= 32°F	31.3	31.2	31.2	31.5	31.4	31.5	31.6	32.3
temperature for site	(= 30°F	29.3	29.2	29.2	29.5	29.4	29.5	29.6	30.3
temperature	(= 28°F	27.3	27.2	27.2	27.5	27.4	27.5	27.6	28.3
Frequency (years in 10)	(≤ 32°F	7.7	6.7	5.4	4.7	3.5	1.7	1.1	0.4
from Base Station	(≤ 30°F	4.9	3.6	2.8	2.2	1.4	0.6	0.5	0.1
graphs	(≤ 28°F	2.3	1.5	1.2	0.9	0.5	0.1	0.1	0.0
Smoothed frequencies	≤ 32°F	7.7	6.7	5.7	4.5	3.3	2.1	1.1	0.3
	≤ 30°F	4.9	3.7	2.8	2.0	1.4	0.6	0.2	0.0
	≤ 28°F	2.3	1.6	1.2	0.9	0.5	0.3	0.1	0.0

TABLE IV DIFFERENCES BETWEEN ACTUAL AND ESTIMATED FREQUENCIES OF GIVEN TEMPERATURES AT ROSS ON WYE 1930-1971 (42 years)

Showing number of estimates within ± 0.5; ± 1.0 years and standard deviations

A - using mean of 3 lowest daily minima each week
B - using the mean daily minima each week

		Weeks							
		1-8	2-8	3-8	4-8	5-8	6-8	7-8	8
≤ 32°F									
Actual Frequency		8.3	7.9	6.9	6.0	4.3	2.1	1.7	0.5
± 0.5	(A	22	20	17	15	17	15	23	41
	(B	27	19	22	14	25	22	27	41
± 1.0	(A	30	32	29	28	29	32	39	41
	(B	38	33	32	31	33	37	38	42
Standard deviation	(A	0.75	0.89	1.04	1.10	1.02	0.75	0.48	0.27
	(B	0.56	0.68	0.74	0.80	0.76	0.67	0.49	0.16
≤ 30°F									
Actual Frequency		6.0	5.0	3.6	2.1	1.7	0.7	0.5	0.0
± 0.5	(A	18	18	16	17	31	34	41	42
	(B	22	23	27	22	35	38	41	42
± 1.0	(A	27	27	31	28	39	40	42	42
	(B	34	32	37	36	40	40	42	42
Standard deviation	(A	0.94	0.99	0.94	0.80	0.61	0.36	0.20	0.08
	(B	0.72	0.76	0.69	0.61	0.49	0.39	0.24	0.05
≤ 28°F									
Actual Frequency		2.9	2.4	1.7	1.2	0.7	0.2	0.2	0.0
± 0.5	(A	18	26	28	35	40	42	42	42
	(B	22	28	36	38	41	41	42	42
± 1.0	(A	31	37	40	40	42	42	42	42
	(B	39	40	41	41	42	42	42	42
Standard deviation	(A	0.87	0.69	0.55	0.40	0.28	0.16	0.05	0
	(B	0.66	0.51	0.39	0.31	0.22	0.17	0.06	0

Figure 1 LONG ASHTON

Smoothed frequencies (years in 10) of extreme minimum temperature (°F) occurring in given periods.

Weeks 1-8 = 1 April to 26 May
3-8 = 15 April to 26 May
5-8 = 29 April to 26 May
7-8 = 13 May to 26 May